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A generalized management information system for computer facilities at educational institutions

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A GENERALIZED MANAGEMENT INFORMATION SYSTEM FOR COMPUTER FACILITIES AT EDUCATIONAL INSTITUTIONS

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THESIS

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ABSTRACT

The problem of managing computer facilities at educational institutions is examined. User categories are defined, and the interrelations between user requirements and the goals/objectives of the facility are discussed. Enumeration of the factors which influence computer facility operation is also accomplished. In addition, management information system theory is applied to the educational computer facility problem, and a proposed generalized management information system is developed. The over-all operation of the MIS is explained, and each component of the system is described. Future development, installation, and validation procedures are discussed.

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I. INTRODUCTION

A. PURPOSE

In practically every field of human endeavor, computer usage has enabled great advances to be made. These strides forward are only a beginning. The possibilities of the human brain using complex computing machines are limitless. One way in which man can move toward the unbounded potential provided by computers is to learn to use these instruments in a more efficient manner.

During the past twenty years, computer hardware technology has been developing very rapidly. Effort has also been expended in the systems programming field. This involves making existing software packages work more efficiently for a particular computer and software operating system. The field of applications programming has not received as much attention as systems programming. Applications programming involves developing software packages to provide new and better solutions to problems. In order to accomplish this task, new algorithms and techniques must be developed. Thus, with new application programs, man is able to more fully realize the capabilities of the existing hardware.

Education is an area in our civilization which significantly utilizes computers and the accompanying technology. Educational institutions generally have different problems

than other segments of the computer user population. Educational computer usage involves functions like those in private industry or government, but, educational computers are also used to teach people how to use computers. Herein lies an area where efficient usage of a computer is very difficult to determine. The problems involved with managing a computer facility at an educational institution are large and complicated.

A need exists to develop some application programming package to provide for more efficient use of computers in educational institutions. This paper will attempt to solve part of this need. A basic design for a Management Information System (MIS) for computer facilities at educational institutions will be evolved.

When implemented, this MIS will aid the manager in evaluating over-all facility operation. Evaluation information will define those operational areas where improvement is needed. The MIS will provide the tools for examining and comparing operating options available to the manager. Also, the MIS will assist the manager in planning for future situations when a change in the facility resources or requirements is anticipated. An additional feature, which should greatly aid the facility manager, provides for making cost information available for either an actual or proposed system. Cost comparisons between various system configurations can then be easily accomplished.

The design level presented in this paper will be aimed mainly at the actual manager of computer operations and his immediate superiors. Sufficient detail necessary for the actual computer programming will not be attempted. The general idea will be to show the feasibility, need, and advantages of the system. If these things can be demonstrated, future development of the MIS will be advantageous.

The method used to accomplish the above task will be to delve into the background of the problems involved in the operation and management of computer facilities at educational institutions. The computer facility at the Naval Postgraduate School provided the actual study model. For two years, the operational problems, both from a user and a management standpoint, were observed. An attempt was made to generalize the specific problems encountered.

A brief look at management information systems theory will assist in understanding the purpose, operation, and advantages of the proposed MIS. Each component of the system, the reports, future development of the MIS, validation/evaluation and installation procedures, and documentation will be covered. Finally, the limitations of the design in its current status, as well as conclusions about the MIS will be discussed.

B. GENERAL BACKGROUND

As has been previously stated the management problem for computer facilities at educational institutions is different than that of management of computer facilities at

government or profit-oriented institutions. The problem has two major causes. The number of user types and the variation of requirements generated by these user types defines the first problem area cause. Difficulty in defining the goals and objectives of the facility, and evaluating the effectiveness of the operation, is the second major cause for the management problem.

1. User Types

Most large educational institutions computer facilities support four basic user types. These are the school administration, contract or other miscellaneous users, faculty, and students. The widely fluctuating requirements placed on the facility, especially by the last two user types, constitute a major management problem for both current and future operations.

a. School Administration

Included in this user type are all jobs performed to assist the operation of the educational institution. Any work to improve or manage the computer facility would also fall under this category. This type of user requirement is fairly predictable, and can be programmed or scheduled on a regular bases. Hence, this usage does not cause major problems unless the load becomes so great that it interferes with accomplishing support for other users. Examples of this user category would be payroll processing, grade sheets, scheduling, and computer systems work.

b. Contract or Other Miscellaneous Users

Included in this user category would be any private industrial concern or government agency which has a contract or an operating agreement with the educational institution for computer and related support. Again, this user type is fairly predictable, and can be scheduled on a regular basis. Normally, this category would not greatly interfere with other user types.

c. Faculty

Any faculty or school staff memeber who is authorized to use the facility defines this user type. The school policy on who within the faculty is allowed computer access, and what limits or restrictions are placed on the use, will define the size of the problem in this user area. The less school placed constraints or control on faculty users, the greater the fluctuation in computer usage.

Scheduling becomes very difficult because of the number and variety of user jobs, many of which are one run affairs. The complexity and running times of user jobs also vary greatly. User trends are hard to establish. There are no common constraints, as at the end of a quarter or semester, when jobs or projects would need to be completed. The above problems, complicated by the fact that the size and type of faculty are susceptible to variations, make future planning in this user area extremely difficult.

d. Student

Any student authorized to use the facility is a member of this user type. This user area generally constitutes a major portion of the computer facility workload. Most of the comments made for faculty users apply in this user area. User trends for this user type may be easier to establish over certain time periods, since these periods usually agree with other school functions. Computer projects would normally need to be completed by the end of the term, and the job load falls off during vacation periods.

It may be advantageous to further subdivide this user category. Possible choices are by curriculum, course, or thesis. In any case, future planning would be greatly complicated by the combination of the above factors, and the wide range of possible student inputs.

2. <u>Goals/Objectives of Facility</u>

The goals or objectives of the facility operation are usually not formally stated or defined in concrete terms. A manager at some operating level must fit school policies/regulations, and user requirements/needs together so that a general mission statement for the facility is satisfied. How this task is accomplished represents another major managerial headache.

a. School Policies/Regulations

Published regulations and operating procedures are often very general and susceptable to wide interpretation. Many policies are not in written form but implied through

higher management by, actions taken, requirements on lower management echelons, and verbal statements. This means that the actual facility operation is subjected to ever shifting goals or objectives. The measurement or determination of goal achievement also fluctuates. Interpreting the current set of goals and objectives and showing that the facility is meeting its requirements represents an important part of the facility manager's job.

b. User Requirements

As individual users of the facility have constraints or schedules within which they must operate, it is necessary for them to take into account computer processing time. Therefore, services such as job processing must be available to the user on some sort of a known basis.

In order to meet the above requirement, computer facilities normally establish a priority system of some type. This priority system determines when a job is to be processed. The basis for priority systems vary from facility to facility. For example, some facilities may use an artifical monetary system, while others may require the user to request computer resources, such as time and core storage space, and determine priority on the resource amounts requested. General guidelines are furnished the user on how priorities are established and what the expected job turnaround times per priority should be.

The priority system established must take into account both user requirements and school policy. The manager must concern himself with the trade-offs between

satisfying user requirements and demonstrating to the school administration that the facility is operating properly.

C. FACTORS INFLUENCING COMPUTER OPERATIONS

There are two major areas which influence computer facility operation. The resources available and the management of the resources determine the capabilities of any computer facility. If the resources are improved or the management of the resources made more efficient, the capabilities of the facility will be increased. The requirements for accomplishing these tasks needs some further thought.

1. Resources

The resources of a facility consist of all physical assets available for allocation by the facility manager. These include hardware, software, manpower, materials, space, and time.

Resource improvement is defined as increasing the overall capability of a facility by obtaining and using more of an existing resource, or acquiring new and better resources. Hiring more personnel or purchasing more materials are examples of using more of an existing resource. Examples of new and better resources are going from second to third generation computing equipment and buying a new application program.

Implicit in resource improvement is some kind of financial outlay. There is always a dollar constraint when expenditures are to be made. Determining which resources

to purchase is a complex problem involving the management area discussed below.

2. Management

In order to improve computer facility management, it is necessary to define what elements comprise the facility management. A generalized management structure for a computer vacility is shown in Figure 1.

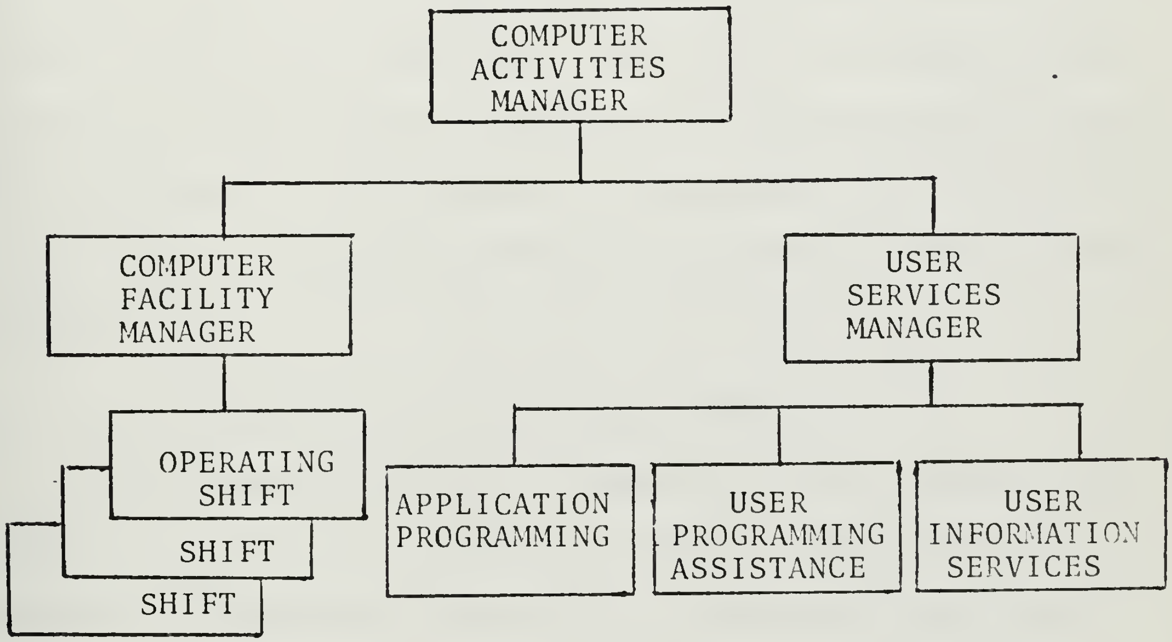

Figure 1. Educational Institution Computer Facility Management Structure

Most computer activities include several operating shifts of computer availability, and some related user assistance services, such as application programming, programming assistance, and user information services. The natural division of responsibility is a manager for the computer operations, and a manager or supervisor for user services.

The manager in charge of all computer related activities is the interface between the college or educational institution administration and the actual operating managers and personnel of the facility.

The management areas of responsibility, include making decisions about current or future resource allocation. Improvement of computer facility management then depends upon the improvement of the decision making process, which controls the facility operation. This can be accomplished by providing better information for the decision makers to use. This is generally the purpose of Management Information Systems (MIS). A brief theoretical discussion of these systems follows.

D. MANAGEMENT INFORMATION SYSTEMS THEORY

An information system is composed of all information gathering, processing, storage, retrival, and display activities. Management information systems are specialized information systems which deal with that subset of all information which is used for decision making. In general, a management information system is defined as "an organized method of providing each manager with all of the data and only those data which he needs for decision, when he needs them, and in a form which aids his understanding and stimulates his action."[1]

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[1] Colbert, B. A., "Pathway to Profit: The Management Information System," Management Services, v. 4, p. 16, September-October 1967.

If a management information system is to meet the requirements defined above, the organizational control or chain of command structure to be serviced by the MIS must be taken into account. The functional areas of control for each manager must be described. This will then help define the subset of information needed for decision making by a particular manager.

The relationships between the organization of an information system and the managerial organization needs more scrutiny. In addition, various MIS design factors should be considered.

1. Organization of MIS

Information systems can be pictured as being organized in the form of a pyramid, and can be subdivided in two ways.[2] Both of these subdivisions are graphically displayed in Figure 2.

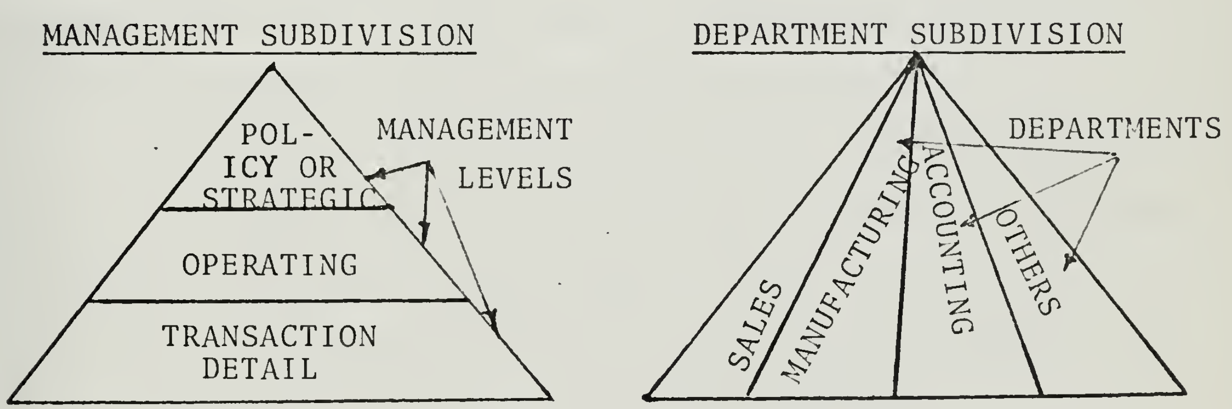

Figure 2. Organization of Information Systems

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[2] Head, R. V., "Management Information Systems: A Critical Appraisal," Datamation, v. 13, p. 22-27, May 1967.

The first subdivision method involves separating the management system into three levels. The transaction detail level, consisting of the raw data base obtained from the day to day operation of an organization, is at the bottom of the pyramid. The next level up in the pyramid is the operating management level. At the top is the policy or strategic planning management level. The latter two management levels consist of aggregating the data obtained from the raw data base, and making decisions with its use.

The functions performed at the policy/strategic management level consist of deciding on objectives of the organization, on changes in the objectives, on the resources used to obtain the objectives, on the policies governing the acquisition, use and disposition of resources. The operating management level concerns itself mainly with the efficient use of available resources toward accomplishing the organizational objectives. The transaction management level assures that specific tasks are performed efficiently.

The second subdivision method is a vertical division of the pyramid into sections, each section representing a different component or department of the organization. For example, a business firm may be comprised of sales, manufacturing, accounting, and other departments.

The above two subdivision methods enable an MIS designer to focus his attention on a particular area, defined by the management levels and the functional departments of the organization. Most MIS designs are directed to the

management level; however, consideration must be given to the information received from, or passed to the other management levels or vertical departments.

2. Design Factors

Hand in hand with the organizational description above, consideration must be given to certain design factors. These design factors are automation, control, and mission. Each of these factors will be examined more closely.

a. Automation

An MIS may be designed to operate in three modes. These are manual, computerized, or a combination of manual and computer. The availability of a computer to the organization, and the desirability/feasibility of a completely computerized system, must be considered from a practical standpoint. Most large scale information systems involving complex operations use combinations of manual and computer operations within the management framework.

b. Decision Control

Does the manager want the MIS to make automatic decisions? This question must be answered for the MIS designer. The automatic decisions are of two types. The first type involves programming the computer to make certain decisions. The second type would be to establish steadfast rules which must be followed by lower level managers. Any MIS system may have a combination of these type decision controls.

The current state of the art involving complex management information systems has not produced any practical

systems where all decisions are programmed to be made by computer. However, there are greater numbers of systems where the machines are programmed to make some of the decisions. Most systems also provide some general rules which the manager must follow.

c. Mission

The MIS designer must decide if the system is to be generalized or specialized. In other words, is the system to be used by a specific organization, or will it be used by many similar type organizations which will make minor modifications in order to specialize the MIS to their own particular needs. Once a system is installed it becomes specialized; however, in the design phase there are major differences between specialized and generalized systems. The generalized system design must be more flexible to handle many slightly different operations and problems. A good generalized system must also be easy to modify in order to perform in a specialized organization.

II. COMPUTER FACILITY MANAGEMENT INFORMATION SYSTEM

A. DESIGN DESCRIPTION

In light of the preceding discussion on MIS theory, the design of the system must take into account the managerial level, and the functional department which is to be serviced. Additionally, decisions about the various design factors must be made. The proposed MIS for educational computer facilities will be examined in this light.

1. Organization

The management level primarily addressed by this MIS will be the operating management level. The organizational area is depicted graphically in Figure 3.

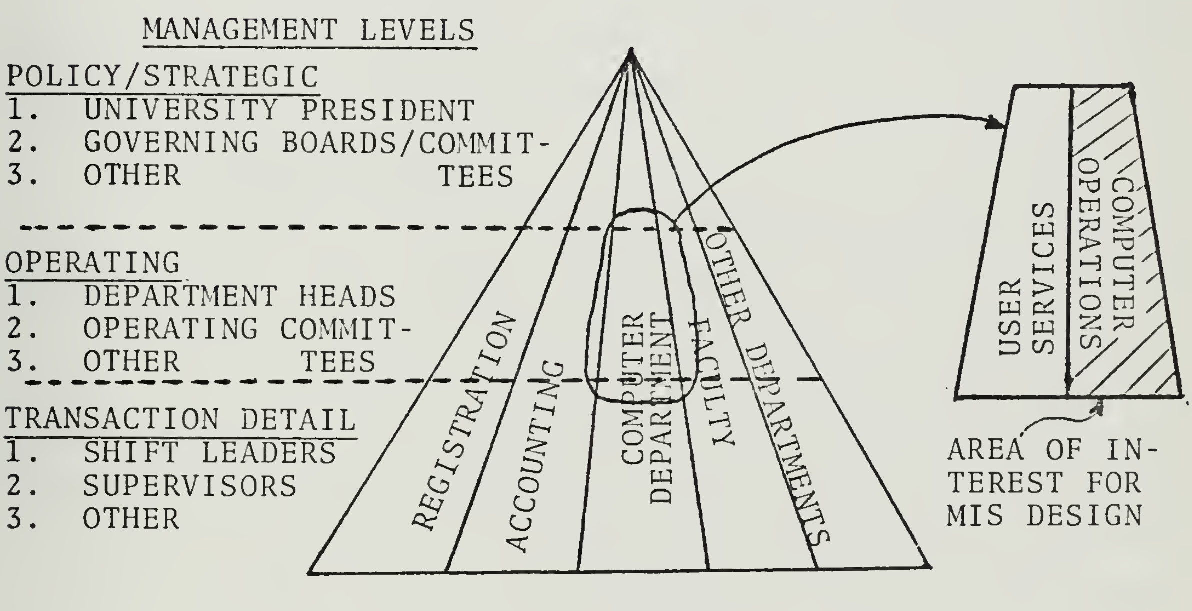

Figure 3. Educational Institution Information System

The actual manager who will operate the system is the manager of the computer facility. He will use the system to test various operating options and make necessary changes within his area of responsibility. He must insure that resources are being properly used to realize the goals/objectives of the facility. He will be required to perform some limited future planning. He will also need the capability of furnishing fairly extensive information to managers making strategic decisions for future planning.

The manager of all computer related activities will be interested in this system, since much of the output and many of the MIS capabilities will be tailored to provide information necessary in his dealings with his superiors/school administration. This manager may also direct the facility manager to conduct studies using the MIS in order to justify requests made to external sources.

2. Design Factors

The aim of the design is to make the MIS completely computerized. The manager will have few rules to follow except that he must operate within his resource constraints. The manager will have the option of allowing some minor automatic computer made decisions in certain areas. The mission of this design will be to provide a generalized system which could be readily used by any computer facility at any educational institution.

B. GENERAL SYSTEM DESCRIPTION

This system will include four major components and a reports section. The components are a data base, a simulation, forecasting models, and managerial decision rules/options. The reports section is composed of three different type reports: scheduled, simulated, and special. Each of the components and the reports will be discussed in more extensive detail in suceeding sections of this paper.

The components make up two sub-assemblies. The data base and simulation are combined to form a model of the facility, while the forecasting portion and the decision rules make up a model for resource management. The system is graphically represented in Figure 4.

C. SYSTEM OPERATION DESCRIPTION

The overall operation of the MIS can be visualized using Figure 4. The information flow and the option possibilities, determined using the legend information, describe how the sub-assemblies and components interact.

1. Computer Facility Model

The computer facility model is a representation of all aspects of the present and future computer facility resources and operations. The purpose of the model is to provide the manager with the historical data and information concerning the current computer operation. In addition, the manager will be able to investigate the consequences of possible future configurations and operations.

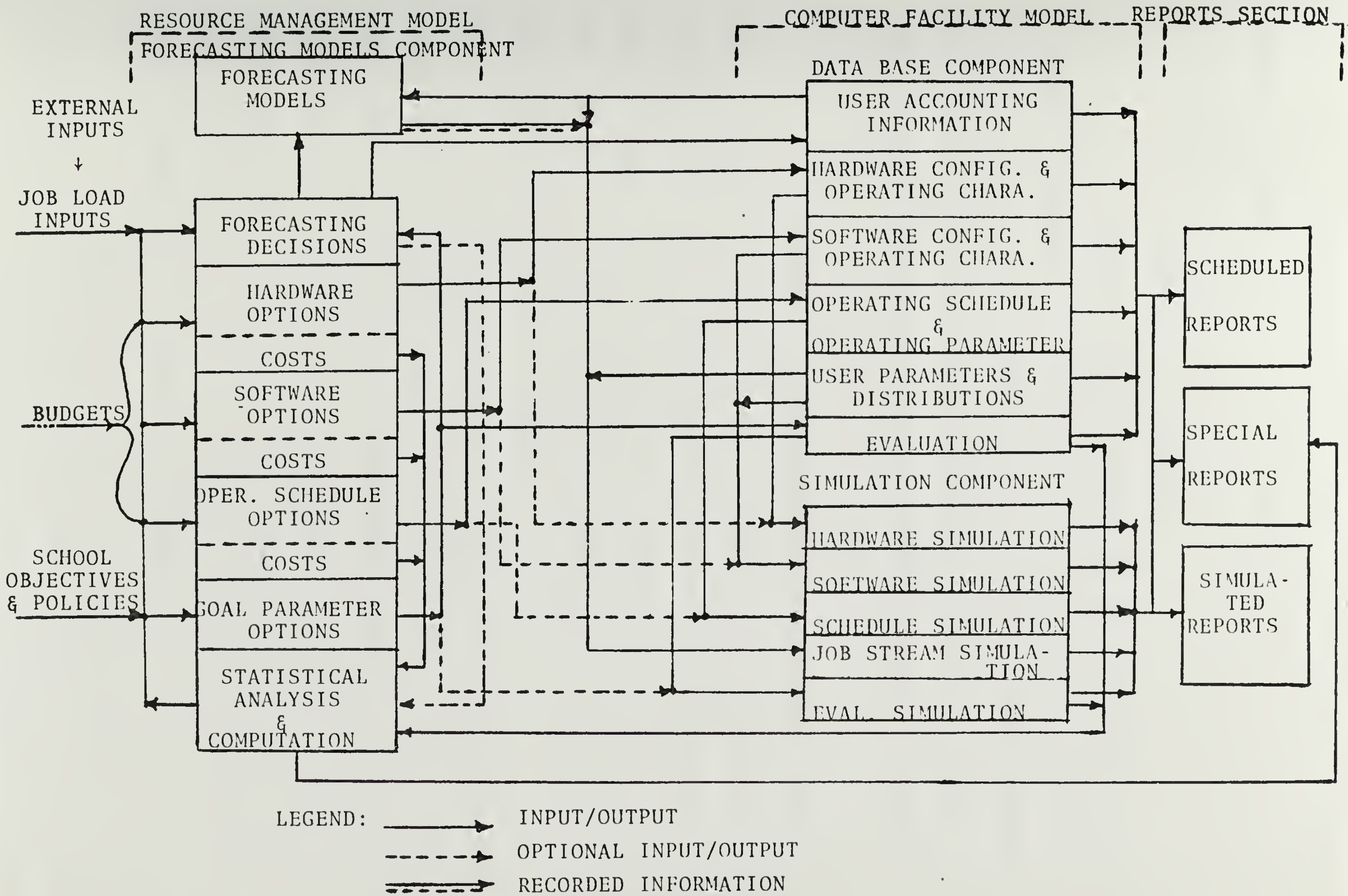

Figure 4. Generalized Management Information System for Computer Facility at an Educational Institute

The elements of this model are a data base which describes current operation, and a simulation for depicting possible future operations. The functions of each component are described below.

a. Data Base Component

The data base component is comprised of six information elements. These elements are user accounting information, hardware configuration and operating characteristics, software configuration and operating characteristics, operating schedule and operating parameters, user parameters and distributions, and evaluation.

There are two types of information input available to the data base. Each element receives input from either historical information/data or from managerial input information. Each information type can be further subdivided into specific information areas which will be discussed in more detail in a later section.

The data base furnishes the simulation with the current hardware/software configuration parameters and operating characteristics, and operating schedules and parameters. Certain job stream or user oriented parameters, such as average print time for certain job classes/priorities, and various user oriented distribution parameters are also furnished to the simulation by the data base.

The data base also furnished inputs to both components of the resource management model. User accounting information is furnished to the forecasting models component.

The evaluation element of the data base collects evaluation data from the current operation, and inputs this data to the managerial decision rules/options component. This input enables the manager to evaluate the operating system with respect to the current goals and objectives.

b. Simulation Component

The simulation is used mainly to provide the manager with the means for seeing what would happen under changing conditions. The simulation can receive input from the data base, or from the resource management sub-assembly, or from both. The evaluation element of the simulation provides input into the statistical analysis and computation element of the decision rules/options component enabling an evaluation with respect to goals/objectives inputs for a simulated computer system.

2. Resource Management Model

The purpose of the resource management model is to describe the resource options available to the manager. Additionally, this model provides a means for determining future job load requirements, so that resource planning for future situations can be accomplished. The two components of this model are the forecasting models component, and the managerial decision rules/options component. The functions of each component are described below.

a. Forecasting Models Component

This component consists of two forecasting models, curve fitting and exponential smoothing, and the necessary

curve fitting routines. The forecasting models component receives inputs from both the data base and the managerial decision rules/options components. The data base input has several possible forms. The input forms are the number of jobs by class or priority by several other criteria. The inputs from the managerial decision rules/options component consists of four decisions:

1. The data base input form and the forecasting time period to use.

2. The curve forms to try to fit the raw data.

3. The curve form which best fits the raw data.

4. The forecasting model to use.

The forecasting models use the inputs and make the necessary calculations to determine future job load forecasts. The job load output form parallels the original input form. This output can then be fed to the simulation component.

The forecast finally used for future planning is recorded for validation purposes. A feedback process, comparing the forecast to the actual data as it is received, enables the manager to decide if the forecast used for future planning is sufficient.

b. Managerial Decision Rules/Options Component

This component is comprised of six elements. These are hardware configuration and option element, software configuration and option element, operating schedule and operating parameters element, goals/objectives parameter option element, forecasting decision/option element and

statistical analysis and computation element. Each element is discussed in more detail in a later section.

The managerial decision rules/options component is a representation of the manager and the actions he can take in the operation of the computer facility. The manager receives external inputs such as budget information, school objectives and policies, and information for determining job loads for the computer. There are two external input categories. These are operational information which concerns the actual physical resources and their capabilities, and cost information which determine the fixed cost or unit cost of the resources.

The above inputs usually form some sort of constraints on the operation of the facility. Therefore, the inputs effect the options available to the manager. From the options which are available, choices are made which then become inputs to the other components of the system.

The inputs to this component from the other system components are processed by statistical routines in the statistical analysis and computation element. Computations are made so as to evaluate either the current operation or an operation under some change in either hardware, software, operating schedule, goals/objectives, or job load (forecast). The costs associated with the various plans, configurations or operations can also be studied and compared. Additionally, forecasts which have been made can be evaluated against the actual data as it is received.

3. Reports Section

The reports available from this MIS consist of three types: scheduled, simulated and special reports. The purpose and composition of each report type is briefly discussed below.

a. Scheduled Reports

The scheduled reports are those required on a regular basis in order to evaluate day to day operation. In addition, scheduled reports establish historical records and other pertinent data, which might be required for external reporting. Scheduled reports have a section for each element of the data base. Thus, there are scheduled reports for user accounting, hardware, software, schedule, parameters/distributions, and evaluation.

b. Simulated Reports

Simulated reports are those which use the simulation to describe the consequences of changing situations. The informational material will generally be the same as in scheduled reports except that it is simulated, and will show what the operation would be under certain "what if" conditions. These conditions could involve physical resource changes, changing requirements from the forecasting models, or changing operational goals and procedures. This type of report is more abbreviated than the scheduled reports, since particular information is not required in this area.

c. Special Reports

The special reports would encompass statistical routines which can be used to help study and evaluate the system, as well as evaluate different procedures and configurations. All cost reporting falls in this category. Combinations of cost and operational efficiency information enables comparisons to be made between completely different computer systems. This type report may be used as justification for requests made to higher management levels.

D. SYSTEM GOALS/OBJECTIVES

The goal of the over-all MIS is to provide the manager with the necessary information and tools for effective decision making. The manager can evaluate the current operation, as well as foresee how the system would operate under either of two types of changing conditions.

The first set of changing conditions are those over which the manager has no real control. The external inputs would generally furnish these changes. The manager can use the MIS to depict operating under these conditions, and make recommendations concerning changes to these external inputs. For example, the increase in expected job load could be simulated. The simulation results might show that the goals and objectives could be met by increasing the hours of operation and increasing the crew size. This solution to an expected problem might require a budget increase, which could be requested. The request might be honored or refused. If refused

an alternative solution must be sought. Once an external decision has been made, the manager must accept the inputs as a constraint.

The second type of condition is changes that the manager can make within his unconstrained area of operation. The operation of the facility might be improved by changing the hardware configuration or by rearranging the software operating system. The manager could find these solutions using the options in the decision rules/options component and the simulation. The best of these alternatives could be implemented. The number of changes and combination of changes available for study and use is very large; therefore, determining which change to use is still no small problem.

It must be emphasized that the goal of the system is <u>not</u> to provide the optimal solution to every problem. In order to accomplish this, every possible option and combination of options open to the manager would have to be tried, costs assigned to each case, predicted results rated, and then the best solution chosen. Due to the number of possibilities, this might very well be too time consuming and costly. In many cases, just finding a good feasible solution or choosing the best of several feasible solutions is sufficient to be of very great value. Consequently, this is what the MIS is designed to enable the manager to do.

E. BENEFITS/ADVANTAGES OF SYSTEM

Most computer facilities have some kind of information system which tells what has happened in the past and what is happening now. The systems in use are usually satisfactory for this purpose.

Existing information systems are usually ineffective for aiding and making decisions about changing conditions of computer operations. Usually, the manager will have to rely on his own intuition concerning the results of certain conditions. He can look at other organizations hoping to find a similar case, or he can use actual experimentation with the facility. Or, if time permits, the manager may use combinations of the above. In any case, the results are very dependent upon the ability, experience and luck of the manager involved.

The experienced manager would have an advantage over an inexperienced manager in using the MIS that is being developed in this thesis. Experience would give the manager some kind of feel for the system. He would know generally in what areas to look for solutions to certain classes of problems. However, the inexperienced manager could use the MIS simulation to gain experience with his computer facility. He would then have some idea about what the problems are that must be faced, and generally how to attack them prior to actually having the problem occur. Hence, an inexperienced manager becomes an experienced manager much faster.

The MIS design discussed in this paper has many benefits, some of which have already been discussed, over the information systems now in use. Primarily, the MIS readily provides the tools and information necessary to make decisions about changing situations, as well as information about current and past operation to include evaluation. Possible problem areas can be examined before they arise. Recommendations, supported by scientific procedures and information, for budget, operating policies and goals can be made to the external decision sources. Thus, proper prior planning can be done to preclude problems.

New hardware and software can be examined using the simulation. This permits evaluation under certain operating conditions without actually buying the new items. New operating schedules or new objectives can be tried using the simulation without using the trial and error system under actual operation. Additionally, the manager can gain valuable insight into the operation of the facility by using the simulation and varying certain inputs to see how the results are affected. The above benefits, as well as others, should certainly make it possible to improve the operation of any computer facility at an educational institution.

III. FUNCTIONAL DESIGN

A. SYSTEM COMPONENT DESCRIPTIONS

In order to understand the operation of the MIS, the composition and operation of each individual component must be studied in more detail. Major areas of concern are discussed for each component. The purpose of this section is to establish general guidelines for the development of the flow charts prior to the actual computer programming.

1. Data Base Component

As previously stated, the data base component consists of six elements. The information, contained in the elements, is of two types; historical data, and managerial input data. Historical data is further divided into job stream information and user parameters/distributions. The managerial input data is divided into four information areas which are as follows:

1) Hardware configuration and operating characteristics.

2) Software configuration and operating chacteristics.

3) Operating schedule and operating parameters.

4) Evaluation data.

The relation between the data base elements and information input types is pictured in Figure 5.

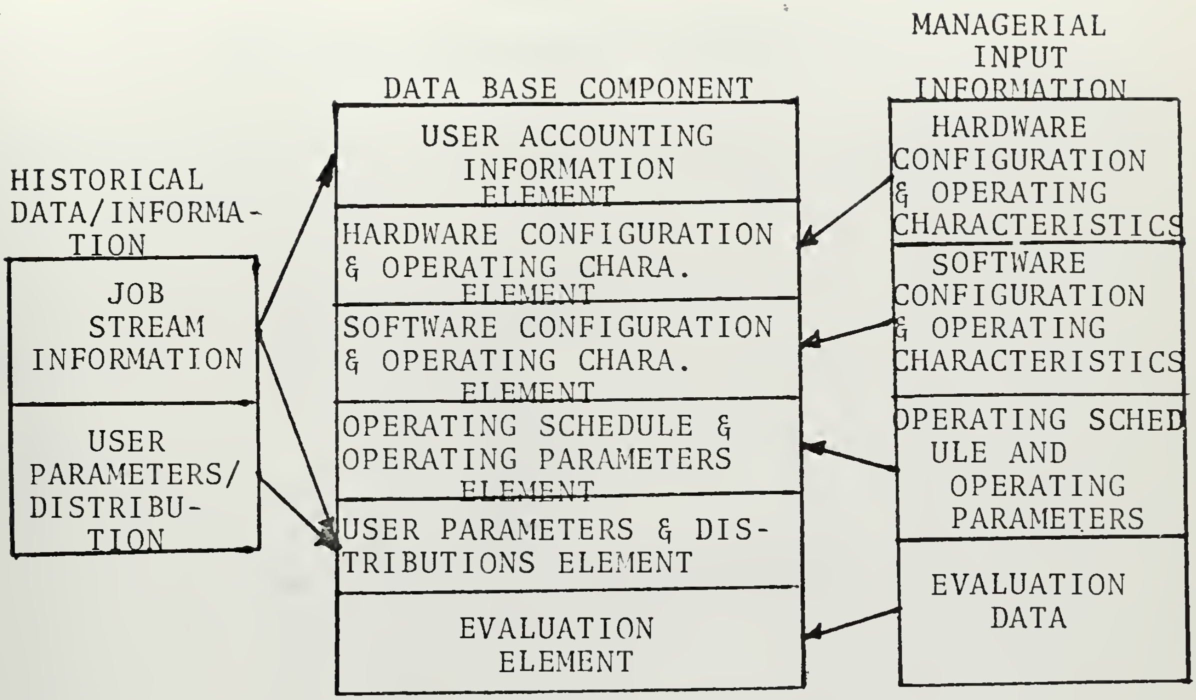

Figure 5. Data Base Information Composition

The purpose of this section will be to study the information composition of the data base. Table I displays the information types and gives examples of specific information classes within each type. How these various informa-types and classes are gathered and used will be discussed below.

a. Historical Information/Data

Historical information/data is defined as any information statistics gathered from any completed job which is no longer in the system. The system is defined as beginning at the point or place where a user turns in his job and ends at the point where the user can pick up his completed

TABLE I

DATA BASE INFORMATION COMPOSITION

I. HISTORICAL DATA

1. Job Stream Information
   a. User Accounting
      (1) User Name
      (2) User Type
         (a) Staff
         (b) Faculty
         (c) Student
         (d) Other
      (3) Job Class/Priority of Job
      (4) Other Information Needed
   b. User Devices Requested
      (1) Input Devices
      (2) Output Devices
      (3) Storage Space
      (4) Other Device Information
   c. Time of Use
      (1) Time Job Submitted
      (2) Computer Usage Time
      (3) Other Time Usage Information
2. User Parameter/Distributions
   a. Parameters Dependent on Hardware/Software
      (1) Device Access Times
      (2) Software Package Access Times
      (3) Other Access/Usage Times
   b. Parameters Dependent Upon Users
      (1) Number of Times Software Packages Accessed
      (2) Number of Times Input/Output Devices Used
      (3) Other Usage Distributions

II. MANAGERIAL INPUT DATA

1. Hardware Configuration and Operating Characteristics
   a. Hardware Listing
   b. Hardware Operating Characteristics
2. Software Configuration and Operating Characteristics
   a. Software Package Locations in Storage
   b. Operating Times for Software Packages
3. Operating Schedule and Operating Parameters
   a. Operating Schedule for Computer
   b. Maintenance Schedule
   c. Crew Descriptions
      (1) Assign Time Equivalent to Each Position Type
      (2) Maximum Crew
      (3) Minimum Crew
4. Evaluation Data
   a. Measurement Criteria
   b. Resources Usage to Measure

job. Historical data has two main purposes. Historical data on the job stream is used as input to the forecasting models. The parameters of the system in use are determined from historical information, and are used as input to the simulation. The actual elements which collect the historical data are user accounting information and user parameters and distributions. The evaluation element must consider the information collected in order to provide a workable picture of the operating conditions.

(1) Job Stream Information. Historical job stream information is used mostly in forecasting future job demand and generally has the purpose of answering the following three questions:

1. Who is using the facility?
2. How are users using the facility?
3. When is the facility being used?

Understanding exactly what is meant by these questions and getting accurate answers to them is the first step in answering difficult forecasting questions.

By determining who, either administration, faculty, student, or other users, is using the facility partially defines the complexity or difficulty of the forecasting problem. The who actually is intended to mean the number of users in each user type. As the number of student and facility users increase, the forecasting problem becomes more difficult. This information, coupled with the school policy as to the objectives and purposes of the facility, is necessary for fully defining the forecasting problem.

The manner in which the users are making use of the facility is also necessary for forecasting. The amount of time, core storage, and devices required are information elements which define the usage area. One of these three elements determines either the job class or the priority for the individual job.

The times that the users are submitting jobs both from a daily, weekly, quarterly or semester basis is necessary to forecast the job stream for any future time. This information can easily be graphically displayed with the particular time axis as the independent variable, and the number of jobs submitted by class or priority as the dependent variable.

Before discussing how the above data are to be collected, consideration must be given as to the purpose of the data and the accuracy needed for its proper use. A determination would need to be made regarding the value of this data collection effort.

Even with good historical information, projecting this information so as to forecast a future user job load requirement, is at best an inexact science. Experience, proper evaluation of the information, and just plain luck all play a part in good forecasting. This means that greater accuracy and more detail will not always mean a better forecast.

With this in mind, the manager must decide what resource expenditure to make in collecting forecast type

data. Resources expended in this effort cannot be used to improve the current operation, but may improve future operation.

Most of the above information will or can be made available either on the job request card, or within the information in the job control language for the job. In most cases, this information is already being collected by computer facilities. Some additions or deletions might be in order after an evaluation is made with regard to accuracy and detail.

(2) User Parameters and Distribution. The second type of historical data involves the user parameters of the facility. These parameters are defined as variable measurements on the operation of the computer facility. The actual measurements depend upon the individual jobs being processed, and the jobs are dependent upon the individual user. Necessarily, there is an over-lap of information in this data type with that in job stream information. The main difference is that job stream information involves the users request for resource usage while the user parameters and distributions are the actual measures of resource usage.

There are a great many parameters for any system. These parameters will then be put into the simulation; hence, it is very important that these parameters be accurate, and that the proper parameters be available.

The necessary parameters are divided into two user oriented areas. The first parameter area is dependent upon the hardware/software configuration. Parameters

information (parameters) going to be subject to great fluctuations or will it be fairly constant? Is this information dependent upon time, operating policy, hardware, software, and users? Additionally, consideration must be given to the required accuracy and detail of the information.

Parameters which are dependent upon the hardware/software system can be directly measured. When a change is made in either hardware/software, a new measurement can be made. Hence, the accuracy of the parameter is dependent solely on the measurement method.

This is not the situation with the parameters which depend upon the users. User oriented parameters may be subject to wide fluctuations as users of the facility change (either by personnel turnover or by learning to use the facility in a different manner). Distributions for these type parameters can be determined, but it is necessary to keep verifying that the distribution has not changed over the periods when the users have changed. So, the accuracy of the user type parameters is dependent on both the measurement method and the verification procedures.

When the above parameters are used in the simulation, it is important to understand the limitations they place on the results. The hardware/software parameters describe a certain computer system in use. If a forecast is made and planning is done, and then the computer system is in some way changed, the forecast and planning may no longer be true for the new system. The user parameters are like forecasts

in themselves. The simulation says future users are going to use the system in generally the same way as past users. This may not be a valid assumption, and would require periodic validation of the parameters in use.

b. Managerial Input Data

The second type of data is managerial input data. This data type is made up of four separate data input areas: hardware configuration and operating characteristics, software configuration and operating characteristics, operating schedule and operating parameters, and evaluation information concerning goals and objectives. Each of the above four areas is described in more detail below.

(1) Hardware Configuration and Operating Characteristics. The hardware configuration is a description of the current equipment set-up as well as a listing of all components. The various component capacities and operating characteristics are necessary. Examples are the number of cards per minute read by a particular card reader, the amount of core storage in the core memory, and the amount of storage space per disc or drum. This input information is matched with the parameters on the hardware in the historical data which is obtained through the measurements methods mentioned previously. Whenever a hardware change is contemplated but no measurement can or has been made, then estimates on the parameters must be fed to the simulation.

(2) Software Configuration and Operating Characteristics. The software configuration is an enumeration

and description of all computer program modules within the operating software system. The description would include times to access various program modules as well as storage locations and storage sizes. Again, this information is matched with the software parameters obtained through measurement methods previously mentioned. Software changes which have not been previously tried might also require some estimates when using the simulation prior to actually setting up a software package and measuring various aspects of its usage.

(3) Operating Schedule and Operating Parameters. The operating schedule and operating parameters are also part of the managerial input. The operating schedule is a time description of when the computer system will be available for operation. The times of operating by normal day of the week, as well as a holiday schedule are included.

The operating parameters are time values placed on various operating personnel positions. A normal operating crew is enumerated and each individual job is given time values. The time value represents an amount of time, either added to the turn-around time for a job if the operating crew is short personnel, or an amount of time subtracted from the turn-around time of a job if the crew is overstrength. Additionally, a minimum crew description is a lower constraint. Thus, the simulation will not work if a minimum crew was not available. A maximum crew is also described. In this case, a penalty time is added if the

maximum crew is exceeded. The turn-around time increases when there are so many people working that they get in each others way.

(4) Evaluation Data. The last element of the managerial input is evaluation information. This includes the measures of effectiveness decided upon to determine if the goals/objectives of the facility are being met. An example of this type information is turn-around time standards for the various job classes or priorities. These objectives should be constantly checked against the job stream flow, and cases should be flagged when a job is found whose standard turn-around time has not been met. If no change in the standards are desired, this evaluation information is fed directly from the data base into the simulation to check future or projected situations.

An additional function of the evaluation element is to enumerate various resources which are being used. For example, the number of hours for various worker positions would be tabulated, the number of boxes of computer paper used would be reported, and other resource usages listed. The aim here is to provide the necessary information for cost analysis.

2. Simulation Component

The purpose of the simulation is to enable the manager to make "good" decisions under changing conditions. The simulation predicts the outcome or operating results when some feature of the current operation is changed in

some manner. Examples of change in the system are: different job loads, equipment changes, personnel changes, system programming changes, and changes in the objectives or goals of the facility.

Inputs to the simulation come from either the managerial decision rules/options component, or from information stored in the data base and/or the forecasting models. The simulation starts at a command from the managerial decision rules/options component. Each of four simulation elements, hardware, software, operating schedule, and evaluation, search for input from the managerial decision rules/options component. The job stream simulation element searches for input from the forecasting models component. In the event that these two components had no inputs, the simulation goes to the data base component for the needed inputs.

The above data inputs are then used to simulate the operation of the facility. The results of the simulation are compiled in report form. The manager can then evaluate the input with the results. Ideally he will be able to find a "good" set of inputs to provide the desired results. The system configuration chosen may not be optimal, but it should certainly be feasible from both input and result aspects.

A graphical representation of the operation of the simulation is shown in Figure 6. The legend information can be used to understand the interaction between the simulation and the other components, as well as the interaction between the simulation elements.

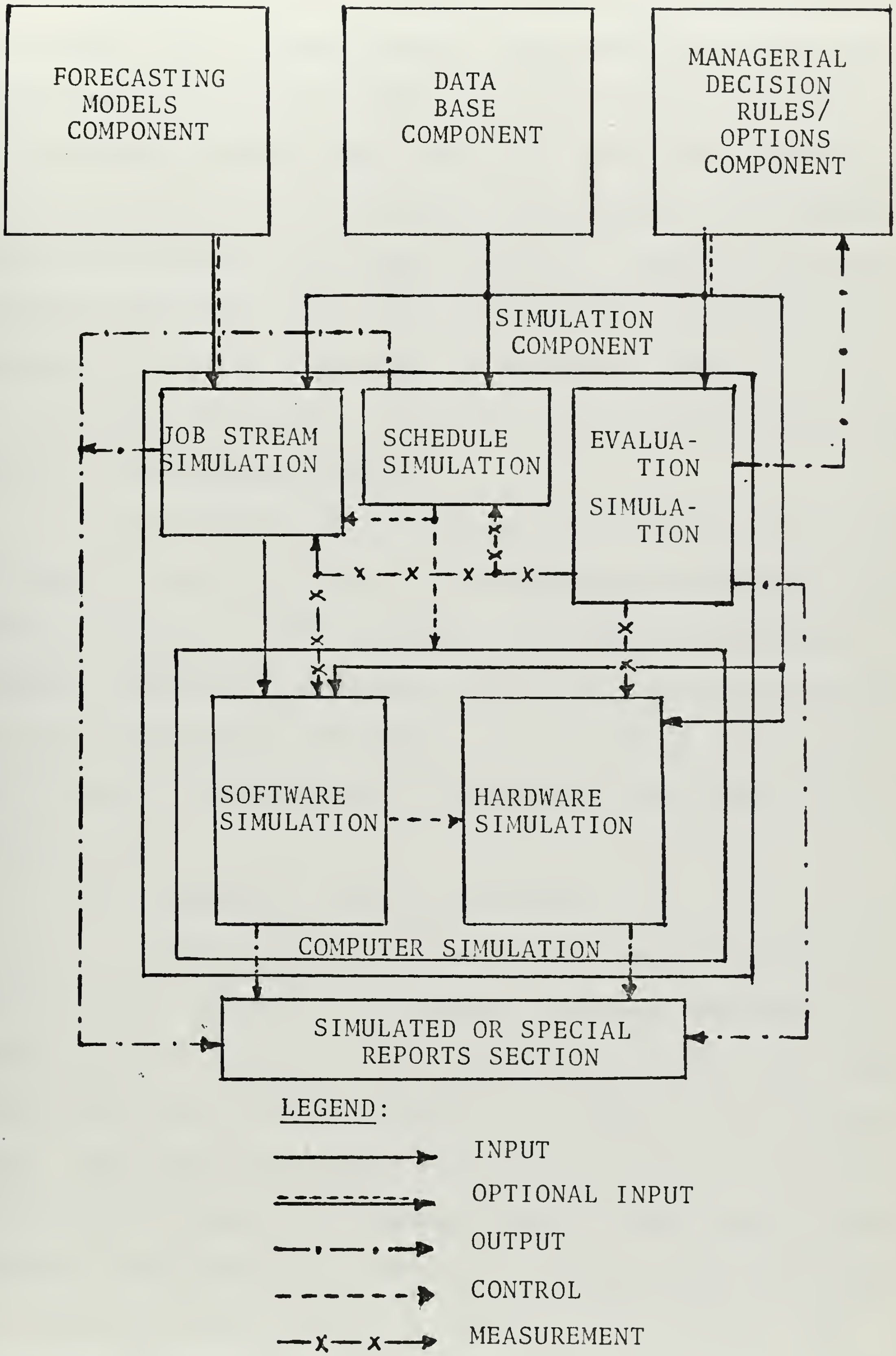

Figure 6. Simulation Operation

Since decisions are going to be made depending upon the studied results from various simulation runs using different inputs, it is extremely important that the simulation be an accurate model of the facility. Also, the simulation model must provide all the options available to the manager in the operation of the actual facility. These facts along with the need for a generalized model make the aspect of programming a computer simulation an extremely difficult task. The simulation component is going to be the most constraining feature of the generalized MIS.

The elements of the simulation parallel part of the data base, as well as, part of the managerial decision rules/options component. The elements are hardware simulation, software simulation, schedule simulation, job stream simulation, and evaluation simulation. The contents, operation and purpose of these various components is discussed in more detail below.

a. Hardware Simulation Element

The hardware simulation, in order to be generalized, must provide for different computer equipment configurations. For example, the managerial or data base input information lists various amounts of storage (core, disc or drum). The simulation must be flexible so that it can operate with any amount of storage chosen within certain limits. Different facilities have different storage capacities, and the simulation must be able to portray all of them. The simulation storage limits are chosen by taking into account

current storage size of available computers and related equipment. Other hardware components would have operating characteristics which are read in as input from the data base or from the managerial decision rules/options component. The simulation of these hardware components (card readers, plotters, printers, remote terminals) depends upon either the operating characteristics data furnished by the equipment manufacturer, or a measurement of some distribution for the operating condition experienced by the equipment.

b. Software Simulation Element

The computer software operating system controls the operation of all computer hardware components. The software simulation element has the analogous function of controlling the operation of the hardware simulation element.

The amount of storage used by the software operating system, library, and other operating packages, as well as their storage locations within the hardware simulation element, is part of the information input to the simulation. The software portion of the simulation accepts the various parameters, which are dependent on the hardware/software configuration, and manipulates the jobs in the job stream accordingly. For example, if a software package is called, it takes a certain amount of time to access the package then another amount of time to operate the package. These times are added to the process time for any simulated job requiring their use.

The software simulation package must have some means of determining which job should be processed. This function is performed by a device sometimes called an initiator. Each job has a job class/priority assigned. As jobs are read into the computer, various lists of the jobs in each job class/priority are generated. The initiator determines which job class/priority to search and which job to pick for processing. The manner in which the initiator determines the actual job for processing involves several options. It is very important that the simulation have initiators with the same number and type of options as are actually available in the existing computer system.

c. Schedule Simulation Element

The schedule portion of the simulation will act as a switch and turn the software element off or on depending upon the existing operating schedule. If the facility does not accept jobs when not operating, the job stream could also be turned off preventing job accumulation. Additionally, the input parameters mentioned in the data base concerning personnel are used within this section to adjust the job processing time. The simulated job processing time will decrease if the operating crew is over strength. Conversely, the processing time will increase if the operating crew is under strength.

The schedule portion should be able to store changes to the initial input, and at the proper time in the simulation, make the necessary changes to the parameters.

For example, starting the simulation with one console operator and two other operating personnel, and at some specific time insert another operator. The input information should also include the holiday schedule. This holiday schedule will be a time listing of regular operating days for which there is reduced or no operation.

d. Job Stream Simulation Element

The job stream simulation element represents the job stream data obtained from either the user accounting information or from the forecasting models and the user parameters. The string of jobs generated has all the same information that a regular job would have; i.e., core storage requested, devices requested, and time requested. This element decides the actual sequence used to present the individual jobs to the software. The software can take a job as it comes and operate on it in the same manner as the regular software operating system. The job is assigned a priority or job class and then is put in a queue waiting for processing by the system. The priority or job class is determined from the input job stream data by initiators or other priority systems as described above.

e. Evaluation Simulation Element

The last element of the simulation is an evaluation element which provides the same general function as the evaluation element of the data base. The input comes from either the data base evaluation element, when there is no change in the projected objectives of the facility, or

from the managerial decision rules/options evaluation element, when a change is anticipated. The aspects of the facilities operation which need to be evaluated are enumerated in the input by standards for operation. As the simulation runs and simulated jobs are processed, checks are made to see if the required standards are being met. If not, certain flagging conditions are reported. Examples of these standards would be turn-around times for various job classes/priorities or central processing unit (CPU) utilization percentage. Also, resources usages would be enumerated as in the evaluation element of the data base. Since there can be many different standards or objectives within different computer facilities, this element of the simulation will require a great deal of measurement capability within the rest of the simulation model in order to provide for generalized usage.

3. Managerial Decision Rules/Options Component

The purpose of the managerial decision rules/options component is to allow the manager to enumerate available computer system configurations. The available computer system configurations, combined with various constraints placed on the operation of the facility by external sources, determine an operational area for the facility. This operational area allows for many managerial options concerning the possible configurations. Simulation studies of the options available within the operational area enable the manager to determine what effect each option has under certain conditions.

The results of these studies are decisions about the facility operation. These decisions usually involve implementing the "best" of several options tried by the manager to solve some problem.

External inputs received such as job load input information, budget information, and school policies and objectives represent constraints. The inputs coming from the budget information can be divided into two areas. The first area deals with resource constraints, such as materials, personnel, and equipment available. The second area involves the costs of the above items on a per unit basis or some cost aspect of the operation, such as a reconfiguration of equipment.

Internal inputs from other components within the system consist of evaluation information on the actual computing system operation or a simulated system operation. These inputs help determine if a change is needed within the operation. If a change is needed, the manager decides which change options he has available. He may then input these change options individually, or in combination, into the simulation, and again receive evaluation information. The manager can then decide which options are the best. The best options may then be implemented when needed.

The composition of the decision rules/options component parallels that of both the data base and the simulation. The elements of this component are hardware configuration and options, software configurations and options,

operating schedule and operating parameter options, goal/objective parameter options, and forecasting decisions/options. A statistical analysis and computation element interfaces between the decision rules/options component, and the inputs from the other components.

Each element of this component must be able to provide all the options open to the manager, as well as be flexible enough to provide the constraints imposed by the external inputs. The cost feature is also important, since it allows the manager to evaluate the performance of any input configuration with the associated cost. The manager will still be required to determine which inputs to use, but the results are in a form that facilitates evaluation and decision making. Each element of this component is discussed with respect to how the rules/options are determined, and how they are used within the MIS.

a. Hardware Configuration and Option Element

The hardware configuration and option element initially requires the manager to furnish to the data base the information requires in the hardware configuration and operating characteristics. This may require measurement of various aspects of the system, or use of manufacturer data on the operating characteristics of the computer and accessory equipment. Once the initial task is performed, no further managerial inputs in this area are necessary, unless some hardware change is made, comtemplated, or a correction to some measurement found. Then, the data change

could be made by card input with some code which would differentiate between a change to be permanently made to the data base, or only used in conjunction with the simulation.

The external constraints placed within this area are due to several factors. Budget can preclude buying new equipment as could space available. Even with this constraint, there are options within this area which can be of use. For example, a rearrangement of the equipment on hand could improve the overall operation. A good simulation of the facility and the proper measurement information input could predict this fact. Using the rearrangement option improves the operation, and requires a management decision to implement the change.

b. Software Configuration and Option Element

The software configuration and option element has a similar function to that of the hardware element above. The hardware is certainly an added constraint, since the larger the software operating system in main core storage, the less core space available to process jobs. After an initial software description is fed into the data base, no additional inputs are needed, unless some change is made or contemplated to the operating system. Any hardware changes which required software changes necessitate managerial inputs to the data base hardware and software elements. Again, a coding arrangement needs to be available for differentiating between changes to the data base and temporary contemplated changes to be used by the simulation.

c. Operating Schedule and Operating Parameter Option Element

The operating schedule and operating parameter option element requires the manager to furnish initial information to the data base component. If the manager wants to check some option involving the operating schedule, he could make several simulation runs using different schedules. Once the manager has decided to make a change, he must make a new entry to the data base inputting the new operating schedule. This element of the managerial options is also constrained by budget and by school policies and regulations.

Considerable thought and study is needed in this area initially, since the manager is required to evaluate the different operator personnel positions with respect to maximum and minimum crews. Also, the manager is required to slow down or speed up the times for job stream processing, depending upon the numbers of the various kinds of operators available during operation. This is an extremely important area which needs constant attention, since other changes within the system will probably affect this area.

d. Goal/Objective Parameter Option Element

The goal or objective parameter option element is used, and changes manipulated, in the same fashion as with the previous elements. These parameters are initially derived from the external input of school policy or regulations. However, the individual manager will need to interpret or translate the policy into some quantifiable feature such as

turn-around time and other measurable information. This may be a difficult task since it requires choosing a measure of effectiveness which is meaningful and usable by the facility users, and at the same time, meets the requirement of showing the school administration that their goals are being met. These two requirements are not always in exact agreement, and this necessitates some sort of compromise.

e. Forecasting Decision/Option Element

The forecasting decision/option element has no similar section in either the data base or the simulation. This section has the mission of receiving job load input and school goal/objective information, and then determining which forecasting model and what data set to use. This information acts as the input to the forecasting models, so that a forecasted job stream can be determined. This section and the forecasting models component of the MIS are always used in conjunction. The actual decisions/options will be discussed in more detail in the explanation of the forecasting models component.

f. Statistical Analysis and Computation Element

The last element of the decision rules/options component is the statistical analysis and computation element. Information is received from the evaluation elements of either the data base or the simulation. The information input is used in certain calculations, some of the computed statistics are analyzed, and the results are fed back into the proper element of the decision rules/options component.

The computations determine what percent of the time the input goals are being met, and what improvements or impairments have been made from the previous runs. Additional capabilities include receiving cost information from a particular set of inputs and comparing it with current costs or with cost inputs on simulation runs. This is done by receiving cost input from the other decision rules/options elements. These costs might be dollars per hour for a certain type worker, or cost per box of computer paper, or cost per new piece of equipment. Then, as either the actual computer system or the simulation uses these resources, they are enumerated in the evaluation element and sent as input to the statistical analysis and computation element, which computes the necessary costs.

4. Forecasting Models Component

The purpose of the forecasting models component, the central element of the forecasting subsystem, is to provide the MIS with several relevant forecasting alternatives. Inputs are received from the data base component and the managerial decision rules/options component. Forecast models, determined from the input data, are used to operate on historical data to provide an output of future job loads. This output from the forecasting models component is the input to the job stream element of the simulation. The output form is in total number of jobs by job class/priority for some particular time period. A feedback process that compares forecast data to the actual data is also part of the procedure for using the forecasting models component.

Figure 7 provides an overview of the forecasting subsystem. Interaction between the components, as well as the operation of the parts of the forecasting models component, are shown. The term control input, as used in Figure 7, means that the component/element receiving the input must perform some action directed by the source of the input. The inputs to the forecasting models component, the techniques of handling the raw data input, the outputs from this component, and the forecasting models themselves, will be discussed in this section.

a. Inputs to Forecasting Models Component

The inputs to this component come from the data base component and the managerial decision rules/options component. Both input types are required for operation of this component.

(1) Input From the Data Base Component. The raw historical data can be thought of as a series of data points plotted with the independent variable being time and the number of jobs per other criteria, such as priority and user type, as the dependent variable. The time period of the input forms should be very flexible so that the historical data can be supplied for any particular day, week, month, quarter/semester, or year.

The raw historical data inputs can be in any of three forms. The first input form in total jobs submitted by class/priority over some time interval. The second input form is jobs submitted by each of the four user types by class/priority over some time interval.

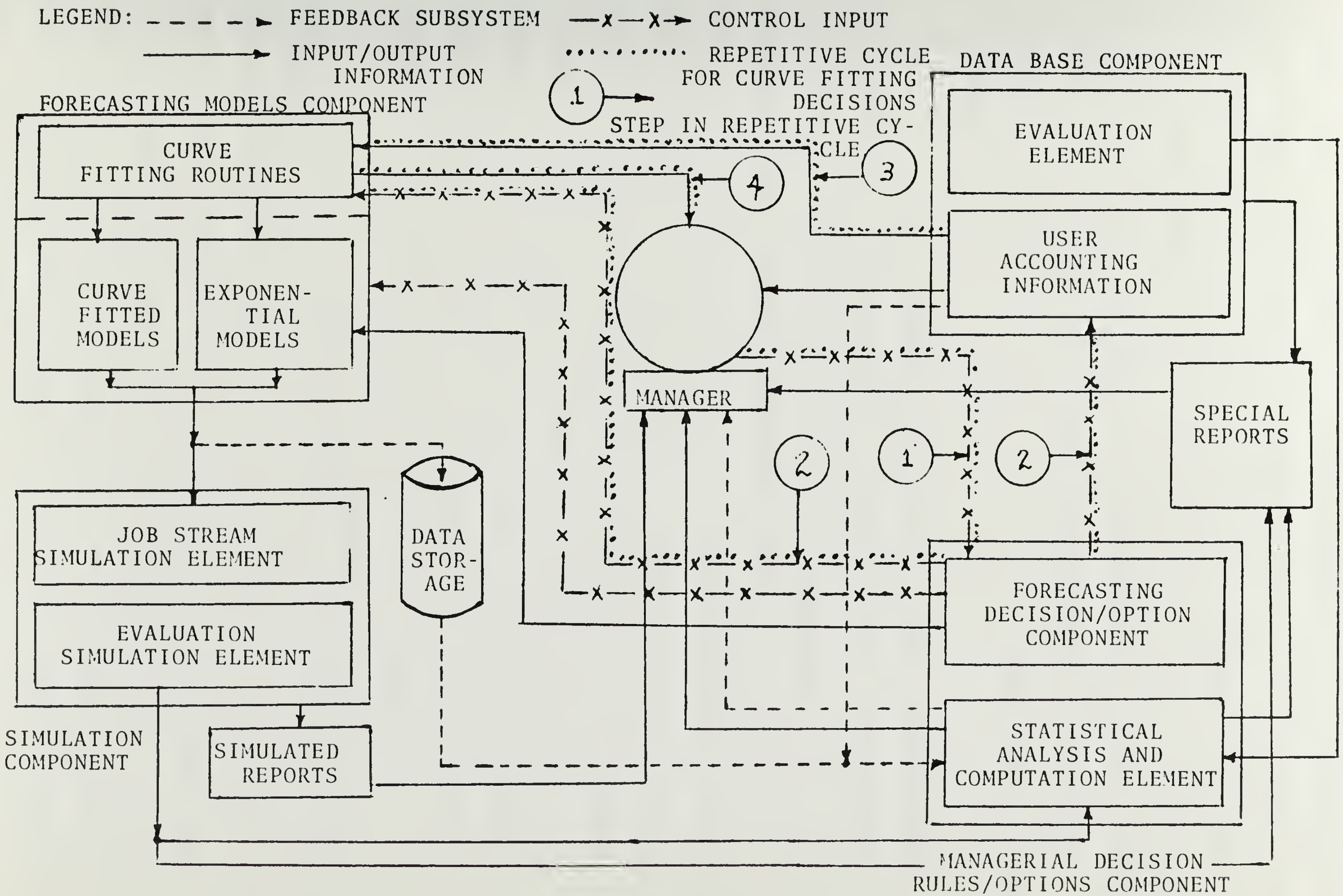

Figure 7. Forecasting Subsystem

The first input form is merely a consolidation of the second input form. The number of jobs submitted by curriculum or particular course by job class/priority for some time period is a more detailed description of the student user type, and is the last input form. This last input form is necessary since the student category is the largest and most flexible user type. Student job input would provide the area of greatest concern in trying to forecast future usage of the facility.

Figure 7 will aid in the understanding of the mechanics involved with actually getting the above information to the forecasting models component. Once the manager makes the decision which raw data input form to use, he makes the necessary entries to the forecasting decision/option element of the managerial decision rules/options component. The forecasting decision/option element then provides a control input to the user accounting information element in the data base which then provides the data to the curve fitting routines. This step may become part of a repetitive curve fitting cycle as shown in Figure 7.

(2) <u>Input from Managerial Decision Rules/Options Component</u>. The inputs from the managerial decision rules/options component indicate which historical data input form to use, what forecast time period to use, and which forecasting method to use. If curve fitting is to be applied, this input also specifies which curve fitting technique to use on the raw data in order to determine the coefficients for the forecast model.

These managerial decisions/options should be a composite of the external inputs given to the manager (job load inputs, budget, school objectives/policies), his experience, the current operation as reflected in scheduled reports, and feedback on the error involved in the forecasts previously made. The external inputs to the manager give him a feel for the accuracy and detail, as well as the time period needed in the forecast. The manager's experience tells him which forecasting methods to try, which curve fitting techniques to use, and finally, which forecase option is the "best" to implement based on the fitted curves and the simulated results.

As the feedback on the forecasts are evaluated, again the manager's experience is needed to determine if the difference between the forecasted conditions is sufficient to either validate or invalidate the overall forecast. An invalidation condition requires a new forecast with the updated historical data, and possibly requires new option studies.

b. Output From the Forecasting Models Component

The output from the forecasting models component is a listing of the number of jobs by job class/priority per some specified time period. The three output types would exactly parallel the inputs from the data base, i.e., consolidated job load, job load by user type, and job load by curriculum or course.

The output is furnished to the job stream element of the simulation. The simulation of the facility then

processes the predicted number of jobs for some specific time period and produces the simulated reports. The forecasted information is recorded for future analysis along with the simulated reports. As actual historical data is generated during the forecast period, it is compared with the forecast data for the same period. Statistical procedures can be applied to determine the difference. This difference information is reported to the manager on demand. An additional option is that the manager can decide beforehand some difference limit, and require the system to report only when the limit is reached or exceeded. In either case, the manager is provided with the necessary information to evaluate not only the forecast, but his decisions and options involving future operations.

c. Forecasting Models/Methods

There are two methods of forecasting available within the proposed MIS. These methods are curve fitting and exponential smoothing.

The curve fitting method involves using a curve fitting technique, called regression, on the raw historical data. The results of the regression analysis are coefficients for the various curve forms and the variances of the deviations of the actual data from the fitted curve. The variance of the deviations is the determining factor in the choice of a curve form. The smaller the variance, the better the data fits the curve. When several models are checked, the computer selects that curve form producing the smallest variance.

When using this method, data from the more distant past is weighted the same as the more recent data. This forecast method might logically be used when the user trend over some specific time interval is expected to remain fairly consistent.

The second forecast method, exponential smoothing, would differ from the first in that the more recent data is weighted more than earlier data. The curve fitting routines are used to decide which curve model to use in conjunction with the smoothing method. The exponential smoothing type technique is used when the user trend is expected to be changing during a time period because of a change in the nature of the users. This method is also used when the current trend is expected to be closer to the future expectations than past trends.

The actual number of forecasting models available with the MIS system should be greater by far than needed by any single facility. It should, therefore, be easy to add or delete models from the system. In many cases, the curve fitting routines needed might already be installed within the program library of the computer facility. An initial managerial decision would be required to determine which of the models to use since the more models installed the less storage space available within the over-all computer system. In other words, there is a trade-off between forecasting capability and operating capability. This comment generally holds for the entire MIS, but the forecasting

portion is the component which is the easiest to modify without destroying the usefulness of the over-all system.

Extensive documentation is needed on each model and its use. Examples should be available for several forecasting situations showing how the models might be applied to the situations. Particular emphasis should be given to show how the results differ depending upon the model used. Each of the models/methods are discussed below in an abbreviated form of what the documentation should include. Extensive mathematic interpretations are not included here, but would be needed in the actual documentation.

(1) Curve Fitting Method/Models. Curve fitting involves determining a user trend. This user trend is expected to be the same for the time period under consideration.

To provide the flexibility necessary for a generalized MIS, numerous individual curve fitting forecast models are necessary. The curve fitting models will use time as an independent variable, and are called time series models. The time series models classification can be further divided into algebraic models, trancendental models, and composite models.

The following paragraphs will briefly describe each model type and individual model used with the system, and give examples of how and when the model would

be applied. More detailed theoretical descriptions of the models and the analysis methods are available.[4]

(a) Algebraic Models. The algebraic time series models are a constant model, a linear model, and polynomial models. The constant model takes the historical data and forecasts in either of two ways. In the first instance, the future load ($\hat{X}_{T+t}$) is forecast to be the same as the current average load ($\hat{a}_T$). The second situation is to forecast a future load equal to the current average load plus some arbitrary constant factor (c). These two constant models are mathematically described as shown:

$$\hat{X}_{T+t} = \hat{a}_T ,$$

$$\hat{X}_{T+t} = \hat{a}_T + c .$$

The linear model consists of fitting a straight line to the historical data and finding the straight line coefficients (a,b). The coefficients are used to forecast a job load ($\hat{X}_t$) for any particular time frame (t). The user trend would be increasing or decreasing linearly. This model is described by the following equation;

$$\hat{X}_t = a + bt .$$

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[4] Brown, R. G., Smoothing, Forecasting and Prediction of Discrete Time Series, 3rd ed., p. 49-174, Prentice Hall, 1962.

Several polynomial models should be available, but the need for fourth or fifth degree polynomial models is doubtful. Again, the degree of polynomial desired would decide the type of curve to fit and the number of coefficients to obtain from the raw historical data. A forecast ($\hat{X}_t$) can then be made according to the derived curve for any particular time frame (t). A quadratic model, with three coefficients (a, b, c), is shown below:

$$\hat{X}_t = a + bt + \tfrac{1}{2}ct^2 .$$

(b) Transcendental Models. The transcendental time series models are exponential models and trigonometric models. The exponential model can be used to describe a process where the rate of growth is proportional to the state of growth. A simple mathematical exponential model is

$$\log \hat{X}_t = \log k + t \log a$$

where k is a constant of proportionality, and a is a ratio of the job load in one year to the job load in the previous year. The values of k and a are determined using a curve fitting routine. The value of the forecast ($\hat{X}_t$) is then determined for any particular time period (t).

The trigonometric models would have the coefficients for the curve determined in the same way. This model would be used when there is seasonal variation apparent. The actual trig models available will be a sine

model, a cosince model, and a combination of both. The cosine and sine models are similar. The cosine model is

$$\hat{X}_t = a \cos \frac{2\pi}{p} (t - t_o) + c,$$

where $\hat{X}_t$ is the forecast for time t, a is the amplitude of the curve, p is the period, t_o is the starting time for the particular period, and c is a constant. A trigonometric identity leads to

$$\hat{X}_t = a \sin \frac{2\pi t}{p} + B \cos \frac{2\pi t}{p} + C,$$

where

$$A = a \sin \frac{2\pi to}{p},$$

$$B = a \cos \frac{2\pi to}{p},$$

$$C = c.$$

The coefficients A, B, and C can be estimated from the data.

(c) Composite Models. The composite models would provide for combining any two or three of any of the above models. In these cases, the coefficients found in the individual models are used in one composite model to plot a forecast curve. The actual curves may be requested and plotted as part of the special report package. These models would be used when the trends for the user types could be distinguished from each other; i.e., when the student trend is increasing linearly while the faculty trend is following the sine model. The forecast for these two

user types would be a combination of the linear model and the trigonometic sine model.

(2) Exponential Smoothing Method/Models. The various smoothing techniques available for use with the curve fitting models are simple exponential smoothing, double and triple exponential smoothing. When the manager decides on an exponential smoothing model for forecasting, the raw data is used to determine the best coefficient for the particular model chosen. A smoothing constant between zero and one, must be determined. This constant depends upon the time period for the forecast and the results desired. If the smoothing constant is small, then random fluctuations are generally eliminated. Large smoothing constants enable a rapid response to a real change in the data. Thus, the smoothing constant determines the weighting of the data.

A mathematical representation for exponential smoothing is

$$S_t(x) = \alpha X_t + \beta\, S_{t-1}(x)$$

where $S_t(x)$ and $S_{t-1}(x)$ represent the forecast made during the present time (t) and the forecast made for the last time period (t-1) respectively, and X_t represents the actual current demand. The smoothing constant is denoted by α with β equal to $1-\alpha$.

Double exponential smoothing is achieved by applying exponential smoothing to the results of smoothing the original data. Essentially, this is using exponential

smoothing twice. This procedure is used to estimate two coefficients such as would be needed when using the linear model. The formula for exponential smoothing is applied first, then the next step is to perform the following calculation:

$$S_t^{[2]}(x) = \alpha\, S_t(x) + \beta\, S_{t-1}^{[2]}(x) \ .$$

The notations $S_t^{[2]}(x)$ and $S_{t-1}^{[2]}(x)$ mean double smoothing and the smoothing constants α and β have the same meaning as in the exponential smoothing. The estimates of the coefficients for the linear model are:

$$\hat{a}_t = 2S_t(x) - S_t^{[2]}(x)$$

$$\hat{b}_t = \frac{\alpha}{\beta} [\, S_t(x) - S_t^{[2]}(x)] \ .$$

The forecast is then given by

$$\hat{X}_{t+T} = \hat{a}_t + \hat{b}T$$

where T is the future forecast time.

Triple exponential smoothing is achieved by applying exponential smoothing to double exponential smoothing. This technique is used to determine three coefficients, which will be needed when using a quadratic model. The development of the mathematical formulas is similar to that for double exponential smoothing.

d. Forecasting Criteria

When using the forecasting models, the facility manager should consider three criteria: accuracy, simplicity of computation, and flexibility to adjust the rate of response. The forecasting accuracy needed for the specific problem under consideration may have a bearing on the flexibility criteria, and both of these criteria will certainly affect the simplicity of the calculations. The interworkings of these criteria should be considered both in the initial decision as to what models should be installed in the system, and which models should be tried and used for any particular situation.

e. Feasibility of the Forecasting Subsystem

Feasibility of this type of forecasting subsystem, in use with a simulation as part of an MIS, has been demonstrated. Retail IMPACT, an inventory management applications program by IBM, uses a simulation within a forecasting subsystem.[5] The purpose of both subsystems is to forecast user demand. In the IBM subsystem, retail products are divided into categories, while in the proposed subsystem, the users are put into categories. The similarities and differences between the two subsystems will be discussed in the following subsections.

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[5] International Business Machines Corporation, Retail IMPACT-Inventory Management Program and Control Techniques-Application Description, 6th ed., p. 36-55, 1970.

(1) Similarities. The forecasting subsystem of IMPACT corresponds to the forecasting component and the forecasting feedback loop of the proposed MIS. The actual computer programming modules should be very similar, since the method/models used for making the forecasts in each subsystem are similar.

Each has a forecasting feedback process. The recorded forecast information is evaluated against actual data as it is received, so that a determination can be made as to the validity of the forecast.

Each subsystem has the capability to feed the forecast data through a simulation in order to evaluate "what if" conditions. The forecasts can be used with other options so that the "best" option can be chosen.

(2) Differences. The difference between the two subsystems exist mainly in the detailed functioning. IMPACT has a more elaborate control section, which provides for more detailed forecast error analysis. This control section can also provide for more computer made decisions, than the subsystem described in this paper.

Retail IMPACT requires greater forecasting flexibility; therefore, more options are needed than in the proposed MIS. The IMPACT computer programming module for forecasting is larger than the anticipated forecasting portion in the proposed MIS.

The simulations of the two systems are different. The simulation in the IBM system is not as complex as the simulation of the computer facility.

B. REPORTS

There are three basic types of output reports made in conjunction with the MIS. The first report type is scheduled reports which are the results obtained from information in the data base. Simulated reports obtained from the results of the simulation are the second report type. The third report type is special reports, which can be the result of either information from the data base, the simulation, and/or the statistical analysis and computation element of the decision rules/options component. These report types are discussed with regard to composition and purpose in the following paragraphs.

1. Scheduled Reports

Scheduled reports are intended to provide the manager with the information necessary to evaluate the current operation of the facility. Certain other historical information is recorded, so that it is available for any external reports or other analytical purposes.

Each element of the data base has at least one report within the scheduled report types. User accounting information is consolidated to show how the four user types are using the facility. This accounting report should be set up so that it can be called by the past day, the past week,

or the past quarter or semester. The software report includes such items as current configuration, number of times various software packages have been used during certain periods of time, average usage time per package, and average access time per package or program. The hardware report includes hours of operation of various equipment, as well as a list of maintenance and the dates performed. The operating schedule and operating parameter element provides report information on the numbers of hours each employee worked, the personnel operating parameters in use, the maximum and minimum operating crews and other schedule related items. The user parameters and distributions provides additional report information indicating when and how the users are using the facility. In this section, graphical reports may be of great value. Parameters could be measured at some specified times, and plotted so that the distributions could be determined.

The evaluation element provides all necessary information to determine if the goals/objectives are being met. This report should include various measurements of key features of the facility: CPU utilization time, job turn-around times between particular hours, average turn-around times for various job classes/priorities, and other measurements of hardware and software operating features.

2. Simulated Reports

The simulated reports provide generally the same type of information as the scheduled reports, except deletions

occur in those cases where specific information, such as employee names, is not needed or available. In general, this report should be somewhat less elaborate; however, in certain areas more detailed information is required than in the scheduled report area. The job stream element report is a consolidation of the information contained in two scheduled reports, user accounting and user parameters and distributions. This information is reported along with distributions used when the forecasting models are involved. The other individual report types correspond to the scheduled reports.

3. Special Reports

In general, special reports are intended to make it easier for the manager to compare various alternative courses of action. The special reports are the more detailed report types. These reports deal with evaluation of various computer facility configurations and operations. Financial information is also available as part of this evaluation data.

When special reports are used in conjunction with the simulation, various possible change alternatives are examined and evaluated. For example, the simulation can be programmed to operate with several possible hardware/software configurations and under different operating schedules. Each change or combination of changes to the present facility operation represents an alternative means of meeting the current goals/objectives of the facility. The special reports can compare the operating results from the simulation runs

against each other and against the results of the computing system in use.

Cost figures for the various facility operations are also available for study and evaluation. The cost feature must be flexible so that it can be used in several ways other than merely computing the straight cost of facility operation. For example, a budget constraint can be placed in some operating area such as overtime pay for personnel. Various operating schedules can then have the operating results evaluated under the overtime pay constraint.

4. Requirement on Reports Section

The report sections must be very flexible. The report section framework should provide for a great many reports, and in all cases, it should be easy to change the reported information in any single report. The report formats should be established so that the individual user facility can change them easily. The entire MIS should be designed so that new reports can be easily obtained.

The programming language used for the report section should be a common one. It should provide extensive format options. It would not be necessary that the language be the same as used in other components of the MIS; however, consideration should be given to the possible interface areas to insure that flexibility is maintained.

The generated reports show the results of the entire computing system. They must be clear, accurate, concise, and have a specific purpose. The external world in

most cases views only the reports generated by the MIS, and has no real concept of how the facility, or the MIS operates. Hence, the over-all favorable or unfavorable impression of the facility is often tied to the information presented in the generated reports. Sufficient effort must be placed in this area so that a favorable condition is presented.

5. Uses for Reports

The manager could use the reports in many ways. In general, the aim of the reports is to help the manager make the necessary decisions to improve his operation when needed, and help him justify his actions to his superiors. Many of these reports may actually be used in correspondence with higher management levels.

The reports make system evaluation easy; thus, comparison of various systems should be fairly simple. Cost information, presented in special reports, will tie dollar figures to computer operating systems. Budget requests can be justified in this manner. Recommendations concerning the manager's constrained area of operation can be made with various report types as justification. Future problems might be anticipated, and planning done to eliminate these problems before they occur. Considerable effort must be made by the manager to fully realize all of the report capabilities, uses, and limitations.

IV. IMPLEMENTATION

A. FUTURE DEVELOPMENT/PROGRAMMING

A preliminary functional design for a management information system has been accomplished in the above sections. In order to achieve the goal of being able to implement this MIS, the design must be made more specific. Hence, the next design stage is the development of the flow charts for the computer program. The development of the computer programs should be accomplished in three phases. These phases are enumerated and discussed below. In addition, the design limitations and problems with the current design are examined.

1. First Phase

During this development phase, the data base and simulation should be programmed. The programming for the data base will basically involve establishing routines to gether the necessary historical data. Subroutines to maniulate the historical data to find parameters/distributions will also be part of this package. The biggest job during this phase will be the development of the computer simulation. Limitations on the simulation capabilities may cause some changes to the overall design. As an integral part of each component design, the information outputs should be put in one of the three report forms. Simulated reports could be completed in this phase, but additions/deletions might occur during later phases.

2. <u>Second Phase</u>

During this phase, the managerial decision rules/options component and the forecasting models component should be developed. Additional scheduled and special report types, dependent upon information from the two newly created components, will be created. Also in this phase, the complete forecasting subsystem should be developed and operated. This includes using all components as separate modules and includes the feedback feature of recording forecast data to compare to actual data when it is available.

3. <u>Third Phase</u>

This phase completes the MIS package. It involves linking all components together and completing all report types. Considerable emphasis should be placed in the linking of the evaluation portions of the data base and simulation to the statistical analysis and computation element of the managerial decision rules/options component. The majority of the special reports, particularly with regard to cost, should be finalized as part of this phase. The entire system should be made to operate as automatically as possible. Changes to the system are made only through the managerial decision rules/options component.

4. <u>Design Limitations/Problems</u>

Certain design limitations or problem areas will need to be considered in the further development of the proposed MIS. The design problems for this MIS can be divided into two areas: problems caused by the design level, and problems caused by the design features.

The level of design discussed in this document is still very general. There is a great deal of room for interpretation of the various functions of the components and reports. This might cause problems with future development. All personnel working on different phases of the design need to agree on the functions and composition of the components and reports, so that integration of the parts will not hamper the overall system operation. Once the computer flow charts are available, this problem area will be eliminated.

The major problem in the design features area is the feasibility of the computer simulation described. There have been many computer simulations, but a completely generalized model is not readily available.[6] The great value of the overall MIS hinges on a "good" simulation, which is flexible enough to be used at many different type computer facilities. If this major obstacle can be removed, completion and putting into operation the rest of the MIS should be easily accomplished.

The current design stage makes it difficult to estimate the final computer program size. The larger the program and the longer the running time for the MIS, the less useful it will be. If the space requirements for the MIS are large, the efficiency of the computer operating system may be impaired since there will be less storage space available for users. There is also a trade-off involved in running

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[6] Goldberg, R. P., Huesman, L. R., "Evaluation Computer Systems Through Simulation," Computer Journal, v. 10, p. 150-156, August 1967.

time. The more time used to operate the MIS, the less time available to process user jobs.

B. INSTALLATION OF MIS

After the above development phases are accomplished, consideration must be given to an installation plan. This plan could vary from facility to facility; however, general guidelines are needed so that an efficient transition from an old MIS to the new MIS can be accomplished.

Prior to installation of the proposed MIS, an extensive study of the particular facility should be accomplished. This installation study does not include a cost feasibility study which should have already been conducted. The decision that the new MIS is feasible and desirable will be the initiating factor for the installation phases. Part of the cost information from the installation phases will have been estimated by the cost feasibility study. The cost data will be needed for the cost evaluation, which is discussed later in this paper.

The installation of the MIS consists of three phases. The first phase involves studying the existing computer operation to gather necessary data and to determine what additional information is needed. The second phase includes actual installation and training on the new system. Validation, corrections and changes, as well as final detailed training is accomplished during phase three.

Reasonable time estimates for an average computer facility for each installation phase may be three to six months

in phase one, and three to four months in each of the remaining phases. These time estimates depend upon the following:

1) The amount of detailed data desired.

2) The required accuracy of the results.

3) The number and complexity of changes to the generalized model in order to specialize the model.

4) The installation method chosen: either installation by facility personnel, or by an outside firm.

5) The competency and number of installation personnel.

1. Phase One

The purpose of the first phase leading toward final installation of the MIS, is to study the current system to determine what information is being collected, how the collected information is being used, the external inputs to the facility, and external requirements put upon the facility. The first phase is further divided into two time periods. During the first time period of this phase, all information needed for the MIS, but not being collected, will be enumerated. The data collection and organization will be conducted during the second time period of the first installation phase. The length of the second time period will depend upon how much data is desired for the initial data base use. The signal for the completion of the first installation phase will be the completion of an initial new MIS data base.

2. Phase Two

The second installation phase will include the training for operator personnel, as well as physical installation and initial testing of the MIS. Since the new MIS

will not be completely operational, the old system will continue to operate. With both the old and new management information systems in use, the overall efficiency of the computer system is lowered. Therefore, this phase should be made as short as possible.

The training portion of this phase would be directed mainly at the operator personnel. Both operator and management personnel should be made familiar with all normal operational manipulations of the MIS. The signal for completion of this phase will be when that portion of the system which produces scheduled reports is completely operational. All scheduled reports may not be required. Only those reports which parallel the minimum necessary information being furnished by the old MIS will be required. When this last step is accomplished, and the reports generated by the new system agree generally with those generated by the old system for the same data, the old MIS can be shut down signaling the end of phase two.

3. Phase Three

The last installation phase has the purpose of providing more detailed technical training, and making necessary additions and deletions to fine tune the system. A continuing training program on the more detailed aspects of the operation and programming of the MIS should be established for operators. The training also involves trouble shooting techniques. The manager and lower supervisors should also be trained in the use of managerial options and the simulation.

Fine tuning of the system will be accomplished by tailoring or modifying the system for the particular facility. Actions in this area are such things as adding, deleting, or changing the various report types, making final decisions on which forecasting models to install, and improving the simulation to more accurately portray the actual computing system. This phase would formally end when the scheduled report information and the simulation accuracy have been validated for some specific time period. The fine tuning process and training will continue as long as necessary to insure proper MIS operation.

C. VALIDATION/EVALUATION

In order for any MIS to be of value, it must provide accurate information. The cost of the system must also be considered such that the results obtained using the system warrant cost of installation and usage. The process involved in determining the answers to the above questions is called validation/evaluation.

There are several validation/evaluation processes which must be used on initial installation, as well as used continuously during operation to insure that the MIS is accurate, economical, and beneficial. These processes will be divided into accuracy validation and cost effectiveness evaluation. The cost evaluation is the most difficult to achieve, since it requires devising measures of effectiveness and determining hidden or future costs.

1. Accuracy Validation

The accuracy validation has two aspects. The first aspect involves measuring the actual system. The second accuracy validation envelops the measurements made by simulation. This latter type validation involves forecasting which, by definition, introduces a forecast error. This implies that accuracy must be defined in terms of its limits.

a. Actual System Accuracy Validation

The current operation of the computer system is related in both scheduled reports and special reports (on demand). Periodic manual measurement and analysis can be performed in the same report areas. The agreement between the report information and the manually gathered data confirms or disputes the MIS accuracy validation for the current computer facility.

Considerable though should be given as to when the manual measurement/observations should be made, and in what areas. If manual measurements are made too often, waste is involved. If the areas studied are of little or no importance, the results are of dubious value. There certainly is a cost, both in efficiency and money, involved in making two measurements of the same aspect of the operation of the system. However, the cost may be even greater if decisions are made using erroneous information or data. Again, the manager must decide the trade-off involved.

b. Simulated System Accuracy Validation

The second type accuracy validation, using the simulation mode, is further divided into two categories. The first of these categories involves determining how proficiently the simulation model portrays the actual system. Category two concerns itself with the accuracy of the simulation under the changing conditions of a projected system versus the actual changed system. The latter category is the most difficult to determine.

(1) <u>Simulation of Actual System Validation</u>. Comparing the actual operation, as reflected in scheduled reports, and the simulation, as depicted in simulated reports, is the process used to either validate or invalidate the simulation accuracy of this category. As long as the data furnished to the simulation is the data used for the scheduled reports, the results from the simulation should generally agree with the scheduled report information.

If there is no agreement, then the simulation model does not accurately describe the actual operation. The two causes for non-agreement are the improper use of the input data and the simulation model itself not reflecting the actual operations in their proper manner or sequence. An example of improper use of input data is in the use of the wrong distribution for some parameter. The second cause for error, improper simulation, occurs when some operation takes more or less time consistently than required in actual practice. A sequencing error is for jobs to be submitted to the printer before finishing in the CPU.

(2) <u>Simulation of Projected System Validation.</u> Accuracy of simulation under changing or predicted conditions is very important, since the manager must rely upon the simulation to get a feel for future operations. This feature is a capability which must be realized in order to gain full utilization of the MIS. If the manager's plan is in error because of the simulation results, the value of the system is sharply curtailed, and may even be negative.

The actual validation process is similar to that already described, except that the simulation is done in advance. The simulation says that the system will operate as shown in the simulated reports if some change is made to the system. Then, when the system is changed, the scheduled reports tell how the actual system operated. If the reports generally agree, then validation holds for simulation under prediction/forecasting.

Again, there can be two causes for non-agreement between the two results. If the simulation model is good, the error should generally be in improper use of input data. This kind of error involves forecasting/predicting, according to past data, future parameter distributions and job load requirements. This kind of error, to some degree, is expected, but it should be within certain plus or minus limits. The model should be flexible enough, so that the simulation of operational changes can be accomplished without destroying the accuracy of the model. An additional check on the validation of the forecasted data

is to compare the recorded forecast with the actual data as it is received. This feature, discussed more fully in a previous section on the forecasting models component, can help the manager decide if the forecast is valid, and what part the forecast plays in the difference between the actual data and the simulation data reports.

2. Cost Evaluation

This process involves determining costs of the current MIS system, projecting costs of the new MIS system, devising a method of evaluating the system through a measure of effectiveness (MOE), and finally, comparing the two systems to see which one better fills the needs of the particular facility. Because cost analysis is difficult, many times new systems are installed without really attempting an impartial cost study/evaluation. In some cases, the costs of the current system are disregarded. Often, no effort is made to develop a measure of effectiveness or compare the alternative systems. This course of action can lead to implementing a costly system without much benefit to the overall operation.

Cost studies should and must be done prior to implementation of the system. After implementation, evaluation of the study should be accomplished. This cost evaluation acts as a cost benchmark of the current MIS for future MIS change situations.

a. Cost of Current MIS

The cost of the current MIS may on the surface seem to be the easiest batch of figures to obtain. In some areas of operation this is true, but there are many obscure, yet important costs involved in any system. This area generally is the cost of future operations due to limited capabilities of the current MIS. This area may be called hidden costs, and every MIS has them. Usually, if hidden costs of some sort are not included in the cost study, the current MIS may erroneously appear to be the most economical alternative.

b. Cost of New MIS

The determination of the cost of the new MIS also is difficult. Installation costs which have to be estimated cannot be easily obtained, and the accuracy may be in question. Much of this question depends upon the current design state of the new MIS. Is the MIS to be developed, or is there an applications program available? Is there an applications program already in use in some other organization? The cost will normally be greater if the MIS is to be developed from scratch versus the situation where an applications program is already available and working. Again, the cost of future operations, due to the expanded MIS capability, is needed. This can be thought of as a reduction in the hidden costs of the current system. This cost may not be reduced to zero by the new system, and must be considered for a complete picture.

c. Hidden Costs Example

As can be seen from the costs of both the old and new systems, hidden costs play a large role in cost studies. The purpose of the following example is to clarify what these type costs are and how they may be evaluated.

Within any system, managers may be required to predict/forecast and plan for the future. Skill, experience, luck, and the frame of mind of the individual manager when he makes the decision affect the forecast, hence future planning. Often wide fluctuations between the true outcome and the expected or forecasted outcome result. Certain error limits are acceptable in forecasts; however, large errors may result in higher costs and less efficiency. Therefore, it is desirable, when forecasting, to eliminate these wide fluctuations.

Using the proposed MIS presented in this paper can eliminate the larger scale fluctuations. This will be done by using better forecasting procedures and scientific evaluation of the forecast. As certain techniques of using the MIS prove effective, standard operating procedures will be developed. These procedures can also aid in eliminating large scale fluctuations. Since large deviations will be reduced, future planning costs will be lowered. Initially a dollar value estimation will be assigned to this cost reduction.

Evaluation of this aspect of the operation can be fairly easy to accomplish. Once the model is installed,

an outside management source can provide forecasts for future operation while the manager makes his own estimate using his old system. Repeating this procedure several times, and studying the results with the actual data as it is accumulated, will enable a comparison of the fluctuation trends between the two methods. The associated costs caused by the fluctuations in each system can be estimated and compared. The actual costs may not be needed. A relative cost rating between the systems may be sufficient.

3. Measuring the Effectiveness of an MIS

A manager must have some means of measuring the operating worth of a system. This usually involves selecting some measurable operating criteria which is exemplary of mission achievement. The relationship between the measurement and mission achievement is called a measure of effectiveness (MOE).

An MOE is a means of evaluating two or more alternatives. There may be a need to develop several measures of effectiveness in order to evaluate various aspects of any operating system. These can then be combined in some manner to provide a final MOE. This will enable the manager to form an ordinal scale for all alternative systems. This does not mean that all managers will evaluate systems in the same manner even if they are using the same measures of effectiveness. Each manager has his own individual methods of determining and weighting various measures of effectiveness.

The proper MOE is a very difficult item to define for most management information systems. Once the MOE has been defined, it is simply a matter of taking or estimating the measurements required for the MOE. The alternative systems can then be rated on an ordinal scale, A is better than B, which is better than C. It should be noted that since the scale is ordinal, no determination can be made as to how much better A is than B or C.

A measure of effectiveness for an MIS will undoubtedly include several measures of effectiveness concerning computer operations. There will be some MOE involving forecasting error. Also included will be some MOE relating rate of response to detecting and reacting to changing operating conditions. The final MOE is dependent upon the worth of the individual measures and the manner in which they are combined.

A closer look at the individual MOE will be beneficial. An example of a measure of effectiveness for a computer facility might be the percent of jobs meeting the objective criteria (turn-around times established by job class/priority) times the CPU utilization percentage for the computing system. The best possible MOE score is one. This example may not be a good MOE for a given computer facility since all priority classes would be considered equally. It may be that meeting the turn-around time for a high priority job is much more important than meeting the turn

around time for a lower priority job. If this was the case, greater weight should be given to the higher priority class percentages.

D. DOCUMENTATION

Documentation for this MIS system will be organized into three classes which will parallel the management levels described in the management information systems theory section. The first and highest documentation class is directed toward the planning or strategic level. The facility manager and his superior will be interested in this level. The inputs to, outputs from, and use of the system, as well as over-all capabilities and limitations, are discussed in this most general documentation.

The next lower documentation level is directed primarily at the facility manager and his immediate subordinates. Operation, installation, and validation will be discussed from a non-technical standpoint in this documentation class. Maximum use should be made of block diagrams or flow charts, showing interworkings between components. Sample problems and operational examples will also be included.

The lowest documentation level is directed at the technicians who operate and trouble shoot the system. Complete flow charts and technical descriptions of each MIS component should be included. Considerable emphasis will also be needed in the area of how to modify each component as well as modify the entire system.

The volume of documentation will be largest at the lowest level, and decreases considerably in each of the next higher classes. The information generally contained in this report will be included in the first documentation class described above.

V. SUMMARY

The computer has become an integral part of our society. Computer usage has sharply increased in the past few years and will continue to increase in the future. There will be an increased demand within our society for personnel who understand and know how to use computers and the accompanying technology.

The curriculums and teaching emphasis in educational institutions reflect societies' needs. This means that there will be continuously increasing requirements placed in computer related activities at educational institutions. Sooner or later the capabilities of educational computer facilities must be increased. This may be accomplished by either increasing/improving the resources or improving the management of the facility or both.

It is not always possible to improve facility capabilities by merely increasing or improving resources. In fact, if the resource allocation is not managed properly, the capabilities may not improve with increased expenditures for resources. Therefore, it is desirable to first find some way to improve the management procedures and processes which govern the computer facility operation. This can be accomplished by finding some way to improve the manager's decision making process which controls resource allocation. An integral part of the decision process and the basis for all decisions is some form of information system.

In order to help the manager to organize the information needed for decision when he needs it and in a form that aids his understanding and prompts his action, a specialized information system called a management information system (MIS) is needed. An MIS must consider the functions of individual managers as well as the organizational structure to be serviced. A properly designed MIS will enable the manager to make sound, timely decisions based upon relevant information.

Consideration must also be given to the fact that most management information systems provide decision information for more than one manager. The MIS used by a subordinate manager is a part of the information system used by his superior. It then becomes advantageous to design the subordinate manager's MIS with an eye on the requirements placed upon his superior. An MIS so designed will more readily provide usable and timely information to managers higher up in the chain of command.

The proposed MIS is composed of two sub-assembly models, made up of two components each, and a reports section. The first sub-assembly model is a representation of the computer facility physical plant either in its current state or some possible future configuration. The components used to provide these features are a data base and a simulation.

The second sub-assembly model deals with resource management. This model is used to describe the resource options available to the manager and provide the tools necessary to determine, with some degree of accuracy, the future job load

requirements. The components of this model are managerial decision rules/options and forecasting models.

The reports section displays the needed information for decisions in a concise and useful form. The three report types available are scheduled, simulated and special. These reports are designed to readily identify operational areas which need improvement.

The MIS proposed in this paper should aid the manager of a computer facility in his decision making process. This decision process involves making decisions about resource allocation concerning both the current operation and future planning. The resources considered by the system are hardware, software, manpower, time, and all materials used in operation.

The scope of the MIS readily provides information in a usable form to decision makers who are concerned with computer operations as a part of their over-all area of responsibility. This MIS can be used in a variety of ways to assist and reinforce the information systems used by the superiors of the computer facility manager. Future planning and budgetary considerations are major areas where this MIS is geared to assist higher level managers.

In order to make decisions about the current operating situation, the MIS must have some means of evaluating the operation. The proposed MIS can evaluate the current operation from two standpoints: efficiency of achieving the goals and objectives of the facility, and cost of operation.

If the evaluation information shows the facility to be operating in an inefficient or costly manner, the manager can begin a search of the operating options open to him. The system will aid the manager in deciding which options to implement in order to improve the over-all facility operation.

In order to make decisions about future planning, any MIS must have some means of examining and evaluating changing situations. The proposed MIS enables the manager to perform these functions in a scientific manner. A forecasting subsystem shows how the facility will operate under changing user requirement conditions. A computer facility simulation may also be used to study various possible operating configurations. The simulated computer operation may be evaluated both with respect to cost and efficiency of achieving goals and objectives. The availability of costing information for each possible computer operating configuration and operating schedule aids the manager in determining which operating options provide the "best" results.

The above capabilities can be further enhanced by the development of standard operating procedures (SOP's) in the use of the MIS. These SOP's, derived from successful techniques of dealing with future changing situations, will help eliminate large scale fluctuations between the plan for the future, and the actual future situations which occur.

Considerable effort will be needed to make the designed MIS operational. The next logical development stage will be flow charts in preparation for the actual computer programming. The feasibility of all components, except the simulation, are fairly certain. If an acceptable simulation can be developed, this MIS, as designed, will enable improved management for educational computer facilities.

Once the MIS has been developed for educational institutions, consideration should be given to making the system usable by other type computer facilities. Managers of computer facilities, used to support either government or private enterprise, also need assistance in making decisions about current operations and future planning. Many concepts presented in this thesis apply to the management problems and situations which face managers of computer facilities servicing other elements of society.

GLOSSARY

CPU - CENTRAL PROCESSING UNIT

The CPU is the "heart" of the computer. It performs computations, logical operations, and causes data to be transferred from place to place within the system. When the efficiency of the computer facility, is considered, it is generally expressed as a percentage usage of the CPU.

FORECAST

A forecast is a formal extrapolation of the past into the future. Implicit estimations may still be involved, but there is a past series of numbers on which to base the estimate. Additionally, it is presumed that observable past patterns will continue in the future. This contrasts with prediction which is an educated guess at what will happen in the future.

INITIATORS

An initiator is that portion of the software operating system which determines which job is to be operated on by the CPU. This task usually involves establishing an order for job classes/priority consideration and then picking the appropriate job from a list of jobs in that job class/priority.

JOB

A job is an individual requirement placed by a user on the computer.

JOB CLASS/PRIORITY

The job class/priority is a system which rates the various type jobs.

JOB LOAD

The job load is an aggregation of individual jobs representing a computer requirement for some particular time period.

JOB STREAM

The job stream is a job load arranged with a particular sequence of the jobs.

MOE - MEASURE OF EFFECTIVENESS

A measure of effectiveness is a measurable quantity which describes goal or objective achievement.

OPERATING SYSTEM

The operating system is a comprehensive set of language translators and service programs operating under supervision and coordination of an integrated control program. It assists the programmer by extending the performance and application of the computing system.

SOP - STANDARD OPERATING PROCEDURE

A standard operating procedure is a step by step method of accomplishing some particular task. The task is one which occurs often enough to develop the "best" procedure for accomplishing it.

TURN-AROUND TIME

The length of time that elapses between submitting a program for testing or production and receipt of the output is turn-around time.

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13. ABSTRACT

The problem of managing computer facilities at educational institutions is examined. User categories are defined, and the interrelations between user requirements and the goals/objectives of the facility are discussed. Enumeration of the factors which influence computer facility operation is also accomplished. In addition, management information system theory is applied to the educational computer facility problem, and a proposed generalized management information system is developed. The over-all operation of the MIS is explained, and each component of the system is described. Future development, installation, and validation procedures are discussed.

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